Prof. Niels Bohr

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Dr. Leland I. Anderson
1615 East River Terrace
Minneapolis 14, Minnesota

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Dr. Leland I. Anderson
1615 East River Terrace
Minneapolis 14, Minnesota
U.S.A.

UNIVERSITETETS INSTITUT
FOR
TEORETISK FYSIK
BLEGDAMSVEJ 15-17, KØBENHAVN Ø
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GL.CARLSBERG
COPENHAGEN

April lo, 1958.

Dr. Leland I. Anderson
1615 East River Terrace
Minneapolis 14, Minnesota.

Dear Dr.Anderson,

On his return to Copenhagen from a longer stay in the United States, Professor Niels Bohr asks me to thank you for your letter addressed to him on August 6,1957, together with your mementoes on Nikola Tesla in which he was greatly interested. The talk on "Atoms and Human Knowledge" was delivered by Professor Bohr on the occasion of the Tesla Centenary without manuscript. Somewhat later, the address has been elaborated further and we are sending you under separate cover a typescript of it. At the same time, we want to draw your attention to the fact that the text is also included in the collection of Professor Bohr's recent papers, which has just appeared with the title "Atomic Physics and Human Knowledge" published by John Wiley and Sons, New York.

Sincerely,

S.Hellmann.

S. Hellmann
secretary.

Niels Bohr

Niels Bohr

Atoms and Human Knowledge *)

It is a great pleasure and honour to take part in this Congress where physicists and technologists from many countries are assembled to pay tribute to the memory of Nicola Tesla to whom we owe advances in physical science initiating a technological development of far reaching consequences. Of course, I do not possess the knowledge and experience as regards electromagnetic power transmission and telecommunication to offer such authoritative exposition of Tesla's great achievements as we are in these days looking forward to receive. However, on this occasion when we are so vividly reminded of how much international cooperation has meant to the progress of science, I have thought that it might be appropriate to give a short account of recent developments in physics, which in a new way have stressed the importance of collaboration and mutual understanding.

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*) Except for certain points which have been elaborated, this article presents the content of the author's address delivered without manuscript at the Nicola Tesla Congress, July 1956.

The exploration of the world of atoms which this century has brought has hardly any parallel in the history of science as regards progress in knowledge and mastery of that nature of which we ourselves are part. However, with every increase in knowledge and possibilities is connected a greater responsibility, and the fulfillment of the rich promises and the elimination of the new dangers involved in the atomic age confront our whole civilization with a most serious challenge, which can be met only by cooperation of all people, resting on a mutual understanding of the human fellowship. For the hope to bridge divergencies caused by differences in people's living conditions and history, it is of importance that science, which knows no national borders and whose achievements are common possession, through the ages has united men in striving to clarify the foundation of our knowledge. As I shall try to show, the studies of atoms, which were to entail such great consequences, and whose progress has rested on a world-wide cooperation, have not only deepened our insight in a new domain of experience, but have also placed general problems of knowledge in a new light.

At first it might perhaps seem surprising that atomic science should contain a lesson of general charatcer, but we must remember that in all stages of its development it has concerned profound problems of knowledge. Thus, already thinkers in antiquity, by assuming a limit for the divisibility of substances, attempted to find a basis for understanding the features of permanency exhibited by natural phenomena in spite of all multifariousness and variability. Even if, during the development of physics and chemistry in the Renaissance, atomic ideas became more and more fruitful, it was right up until this century a widespread opinion that one had here to do with a hypothesis. Thus, it was taken for granted that our sense organs, themselves composed of practically innumerable atoms, were much too coarse to observe the smallest parts of matter. This situation was, however, to become essentially changed by the great discoveries at the turn of the century and, as is well known, progress in experimental technique made it possible to record directly effects of single atoms and to obtain information about the more elementary particles composing the atoms themselves.

Notwithstanding the deep influence exerted by ancient atomism on the development of the mechanical conception of nature, it was, however, the study of immediately accessible astronomical and physical experience which made it possible to trace the regularities expressed in so-called classical physics. With Galileo's program, according to which the account of phenomena must be based on measurable quantities, one succeeded in liberating oneself from comparisons with feelings of strain when we move and with motives for our actions, which had so long hindered the rational formulation of mechanics. Thus, in Newton's principles, one found the foundation of a deterministic description permitting, from the knowledge of the state of a physical system at a given moment, the prediction of the state at any subsequent time. Along such lines, it was also possible to account for electromagnetic phenomena. This required, however, that the description of the state of the system include, besides the positions and velocities of the electrified and magnetized bodies, the strength and direction of the electrical and magnetic forces at every point of space at the given moment.

The conceptual framework characterizing classical physics was long thought to provide the right tool for the description of all physical phenomena and not least was it suited to utilize and develop atomic ideas. Of course, for systems such as ordinary bodies which are composed of an enormous number of constituents, there could be no question of an exhaustive description of the state of the system. Without abandoning the deterministic ideal, it became possible, however, on the basis of the principles of classical mechanics, to deduce statistical regularities reflecting many properties of bodies. Even if the mechanical laws of motion permit a complete reversal of the course of the single processes, the characteristic feature of irreversibility in heat phenomena found a full explanation in the statistical energy equilibrium resulting from the interaction of the molecules. This great extension of the application of mechanics further emphasized the indispensability of atomic ideas in the description of nature and opened the first possibilities of counting the atoms of the substances.

The clarification of the foundation of the laws of thermodynamics was, however, to open the way to the recognition of a feature of wholeness in atomic processes far beyond the old doctrine of the limited divisibility of matter. As is well known, it was the closer analysis of the phenomena of heat radiation which became the test of the scope of classical physical ideas. The discovery of electromagnetic waves had already provided a basis for an understanding of the propagation of light, permitting in great measure an explanation of the optical properties of substances, but the endeavours to account for the radiation equilibrium confronted such ideas with insurmountable difficulties. Just the circumstance that one had here to do with arguments based on general principles and quite independent of special assumptions regarding the constituents of the substances led Planck, in the first year of this century, to the discovery of the universal quantum of action which showed clearly that the classical physical description is an idealization of limited applicability. In phenomena on the ordinary scale, the actions involved are so large compared to the quantum that this can be left out of consideration. However, in proper quantum processes, we meet regularities which are completely foreign to the mechanical conception of nature and which defy pictorial deterministic description.

The task with which Planck's discovery confronted the physicists was nothing less than, through a thorough analysis of the presuppositions for the application of our most elementary concepts, to provide room for the quantum of action in a rational generalization of the classical physical description. During the development of quantum physics, entailing so many surprises, we have time after time been reminded of the difficulties of orienting ourselves in a domain of experience so far from that to whose description our means of expression are adapted. The rapid progress has been made possible by a wide and intensive collaboration between physicists from many countries, whose diverse approach has helped in a most fruitful way to bring the problem into ever sharper focus. At this occasion, of course, it will not be possible to deal in detail with individual contributions, and as a background for the following considerations I shall only remind you briefly of some of the main features of the development.

While Planck cautiously limited himself to statistical arguments and emphasized the difficulties, in a more detailed description, of abandoning the classical foundation, Einstein - in the same year that he gave the framework of classical physics such harmonious completion in establishing the theory of relativity - daringly pointed to the necessity of taking the quantum of action into account in individual quantum phenomena. In particular he showed that the description of observations regarding photoelectric effects requires that the transmission~~s~~ of energy to each of the electrons expelled from the substances just corresponds to the absorption of a so-called radiation quantum. As there could be no question, however, of simply replacing with a picture of particles the idea of waves indispensable for the account of the propagation of light, one was here confronted with a peculiar dilemma, the solution of which was to require a thorough analysis of the scope of pictorial ideas.

As is well known, this question was further accentuated by Rutherford's discovery of the atomic nucleus which, despite its minuteness, contains almost the whole mass of the atom and whose electrical charge corresponds to the number of electrons in the neutral atom. On the one hand, one got a simple picture of the atom immediately suggesting the application of mechanical and electromagnetic ideas. On the other hand, it was clear that, according to classical physical principles, no configuration of electrical particles will possess a stability necessary for the explanation of the physical and chemical properties of the atoms. In particular, according to classical electromagnetic theory, every motion of the electrons around the atomic nucleus would give rise to a continual radiation of energy implying a rapid contraction of the system until the electrons became united with the nucleus into a neutral particle of dimensions vanishing relatively to those which must be ascribed to the atoms. In the hitherto entirely incomprehensible empirical laws for the line spectra of the elements, one got however a hint as to the decisive importance of the quantum of action for the stability and radiative reactions of the atoms.

The point of departure became here the so-called quantum postulate, according to which every change in the energy of an atom appears as the result of a complete transition between two of its stationary states. By further assuming that all atomic radiative reactions involve the emission or absorption of a single light quantum, it became possible to determine from the spectra the energy values of the stationary states. Evidently, within the framework of a deterministic description, the explanation of the indivisibility of the transition processes and their appearance under given conditions was excluded. However, by means of the so-called correspondence principle, according to which, through a comparison with the classically expected course of the processes, one looked for directives for a statistical generalization of the description compatible with the quantum postulate, it was possible to get a survey of electron bindings in the atoms which reflected many properties of the substances. Still, it became more and more clear that, in order to obtain a consistent account of atomic phenomena, it was necessary to renunciate to a still higher degree the use of pictures and by a radical reformulation of the whole description to provide room for all features implied by the quantum of action.

The solution which was reached through ingenious contributions from many of the most eminent theoretical physicists of our time was surprisingly simple. Just as in the formulation of relativity theory, adequate tools were found in highly developed mathematical abstractions. The quantities which in classical physics are used to describe the state of a system are replaced in the quantum mechanical formalism by symbolic operators whose commutability is limited by rules containing the quantum. This implies that quantities such as positional coordinates and corresponding momentum components of particles cannot simultaneously be ascribed definite values. Just in this way the statistical character of the formalism appears as a natural generalization of the description of classical physics. This generalization further permitted a consequent formulation of regularities which limit the individuality of identical particles and which, like the quantum itself, cannot be expressed in customary physical pictures.

By means of the quantum mechanical methods it was possible within a few years to account for a large domain of experience regarding the physical and chemical properties of substances. One succeeded not only in clarifying in detail the binding of electrons in atoms and molecules, but also in obtaining deep insight into the constitution and reactions of atomic nuclei. In this connection we may mention that the early discovered probability laws for the spontaneous radioactive transmutations have been harmoniously incorporated in the statistical quantum mechanical description. Also as regards the properties of the new elementary particles which in the last years have been observed in the study of transmutations of atomic nuclei at high energies, continual progress has been obtained by adapting the formalism to the invariance requirements of relativity theory. Still, we are here confronted with new problems the solution of which obviously demands further abstractions suited to combine the quantum of action with the elementary electric charge.

In spite of the fruitfulness of quantum mechanics within such a wide domain of experience, the renunciation of accustomed demands on physical explanation has caused many physicists and philosophers to doubt that we are here dealing with an exhaustive description of atomic phenomena. In particular the view has been expressed that the statistical mode of description must be regarded as a temporary expedient which, in principle, ought to be replaceable by a deterministic description. The thorough discussion of this question has however led to that clarification of our position as observers in atomic physics which has given us the epistemological lesson referred to in the beginning of this lecture.

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As the goal of science is to augment and order our experience, every analysis of the conditions of human knowledge must rest on considerations of the character and scope of our means of communication. The basis is here, of course, the language developed for our orientation in the surroundings and for the organization of human communities. With the increase of experience, however, the question raised itself repeatedly as to the sufficiency of the concepts and ideas incorporated in daily language. Because of the relative simplicity of physical problems, they are especially suited for the investigation of the use of our means of communication, and just through the development of atomic physics we have been taught how, without leaving common language, it is possible to create a framework sufficiently wide for an exhaustive description of new experience.

In this connection it is imperative to realize that, in every account of physical experience, one must describe experimental conditions as well as observations by the same means of communication which are used in classical physics. In the analysis of single atomic particles, this is made possible by irreversible amplification effects - such as a spot on a photographic plate left by the impact of an electron, or an electric discharge created in a counter device - and the observations concern only the information thus gained as to where and when the particle is caught on the plate or its energy at the arrival at the counter. Of course, this information presupposes knowledge of the position of the photographic plate relative to the other parts of the experimental arrangement, such as regulating diaphragms and shutters, defining space time coordination, or electrified and magnetized bodies which determine the external force fields acting on the particle and permit energy measurements. The experimental conditions can be varied in many ways, but the point is that in each case we must be able to communicate to others what we have done and what we have learned, and that therefore the functioning of the measuring instruments must be described within the framework of classical physical ideas.

As all measurements thus concern only bodies which are sufficiently heavy to permit in their description the neglect of the quantum, there is strictly speaking no new observational problem in atomic physics. The amplification of atomic effects, which makes it possible to base the account on measurable quantities and which gives the phenomena a peculiar closed character, only emphasizes the irreversibility characteristic of the very concept of observation. While,within the frame of classical physics,there is no difference in principle between the description of the measuring instruments and the objects under investigation, the situation is, however, essentially different regarding quantum phenomena. Not only does the question of the stability and individuality of the objects themselves point to a limitation of the idea of well defined atomic systems, but even within the large domain of experience where this idea can be upheld, the quantum of action imposes restrictions on the description of the state of the systems by means of space time coordinates and momentum energy quantities. Since the deterministic description of classical physics rests on the assumption of an unrestricted compatibility of space time coordination and dynamical conservation laws, we are here obviously confronted with the problem of whether, as regards atomic objects, such a description can be fully retained.

The clarification of this main point was furthered especially by reference to the role of the interaction between objects and measuring instruments in the description of quantum phenomena. Thus, as pointed out by Heisenberg, the quantum of action implies that locating an object in a limited space time domain involves an exchange of momentum and energy, being the greater the smaller the domain chosen, between instrument and object. It was therefore of utmost importance to investigate to what extent such interaction entailed in observation can be separately taken into account in the description of phenomena. This question has been the focus of much discussion, and many proposals aiming at complete control of all interactions have appeared. In such considerations, however, due regard is not taken to the fact that the very account of the functioning of the measuring instruments involves that any interaction, implied by the quantum, between these and the atomic objects be inseparably entailed in the phenomena.

Indeed, every experimental arrangement permitting the registration of an atomic particle in a limited space time domain demands fixed measuring rods and synchronized clocks which, according to their definition, exclude control of momentum and energy transmitted to them. Conversely, any unambiguous application of dynamical conservation laws in quantum physics requires that the description of the phenomenon in question involves a renunciation in principle as regards detailed space time coordination. This mutual exclusion of the experimental conditions necessary for the application of the elementary concepts implies that the whole experimental arrangement must be taken into account in the well defined description of the phenomena. In this connection, the indivisibility of quantum phenomena finds its consequent expression in the circumstance that every definable subdivision would require a change of the experimental arrangement with the appearance of new individual phenomena. Thus, the very foundation of a deterministic description has disappeared and the statistical character of the predictions is evidenced by the fact that observations corresponding to different possible individual processes will in general appear under the same experimental conditions.

Such considerations have not only clarified the already mentioned dilemma regarding light propagation, but have also completely solved the corresponding paradoxes brought up by later development regarding pictorial representation of the behaviour of material particles. Here, of course, we cannot seek a physical explanation in the customary sense, but only that removal of any apparent contradiction which is all we can demand in a new field of experience. However great the contrasts exhibited by atomic phenomena obtained under different experiemntal conditions, such phenomena must be termed complementary in the sense that each of them is well defined and that together they exhaust all definable knowledge about the objects in question. The quantum mechanical formalism, aiming directly at a comprehension of observations obtained under experimental conditions described by simple physical concepts, just gives an exhaustive complementary account of a very large domain of experience. The renunciation of visualizable pictures involves only the state of atomic objects, while the foundation for the description of the experimental conditions, as well as our freedom to choose these, is fully retained. The whole formalism, whose application is well defined only as regards closed phenomena, must in all such respects be considered a rational generalization of classical physics.

In view of the influence of the mechanical conception of nature on philosophical thinking, it is understandable that in various circles the notion of complementarity has been regarded as entailing a reference to the subjective observer incompatible with objectivity of scientific description. Of course, in every field of experience we must retain a sharp separation between the observer and the content of the observations, but we must realize that the discovery of the quantum of action has thrown new light on the very foundation of the description of nature and revealed hitherto unnoticed presuppositions for the rational use of the concepts on which the communications of experience rest. In quantum physics, as we have seen, an account of the functioning of the measuring instruments is indispensable for the definition of phenomena and we must, so-to-say, draw the separation between subject and object in a way which in each single case secures the unambiguous application of the elementary physical concepts used in the description. Far from containing any mysticism foreign to the spirit of science, the notion of complementarity points to the epistemological conditions in our position as regards description and comprehension of experience in atomic physics.

Just as in earlier progress in physics, the lesson received through the development of atomic science regarding general conditions of human knowledge has naturally given rise to renewed consideration of the use of our means of communication for objective description in other domains of experience. Notlleast, the particular emphasis on the observational problem raises the question of the position of living organisms in the description of nature and of our own situation as thinking and acting beings. Even if, within the frame of classical physical ideas, it was possible to a certain extent to compare organisms to machines, it was clear that such comparisons did not properly recognize many of the characteristics of life, and the inadequacy of the mechanical conception of nature, as regards the account of man's situation, found expression particularly in the difficulties entailed in the primitive distinction between soul and body.

The problem with which we are here confronted are obviously connected with the fact that the description of many aspects of human existence demands a terminology not immediately resting on simple physical pictures. However, just the recognition of the limited applicability of such pictures in the account of atomic phenomena gives a hint as to how, confronted with the problems of biology and psychology, we shall comprehend experience within the frame of an objective description. As before, it is here important in each single case to be aware of the separation between the observer and the content of the communications. While, in the mechanical conception of nature, the subject-object separation was fixed, room for a wider description is provided by the different placings of such a separation entailed in the conditions for the consequent use of concepts.

Without attempting any exhaustive definition of organic life, we may say that a living organism is characterized by its integrity and adaptability, which implies that the description of internal functions of an organism and its reaction to external stimuli often requires the word purposeful, foreign to physics and chemistry. Even if the results of atomic physics have found multifar~~r~~ious applications in biophysics and biochemistry, the closed individual quantum phenomena exhibit, of course,no feature suggesting the notion of life. As we have seen, the description of atomic phenomena, exhaustive within a wide domain of experience, rested on the free use of the measuring instruments necessary for the well defined application of the elementary concepts. In a living organism, however, such a distinction between measuring instruments and objects under investigation can hardly be fully carried through and we must be prepared that every experimental arrangement aiming at a description, well defined in the sense of atomic physics, of the functioning of the organism, will be incompatible with the display of life.

In biological research, references to features of wholeness and purposeful reactions of organisms are used along with the ever more detailed information on their structure and regul~~arity~~atory processes that has brought such great progress not least in the field of medicine. We have here to do with a practical approach to a field where the means of expression used for the description of its various aspects refer to mutually exclusive conditions of observation. In regard to attitudes termed mechanistic and finalistic, it must be realized that we are not dealing here with contradictory viewpoints, but with a feature of complementarity connected with our position as observers of nature. In order to avoid misunderstanding, it is essential however to note that - in contrast to the account of atomic regularities implied by the quantum of action - the description of organic life and the evaluation of its possibilities of development cannot, of course, aim at any completeness, but only at sufficient width of description.

In the account of psychical experiences we meet with conditions of observation and corresponding means of expression which are still more removed from the terminology of physics. Quite apart from the extent to which it is necessary and justified to use words like instinct and reason in the description of the behaviour of animals, the word consciousness, applied to oneself as well as to one's fellow beings, is indispensable in the description of the human situation. While the terminology adapted to orientation in the environment could take as its starting point simple physical pictures and ideas of causality, the account of states of our mind, since the origin of language, required a typical complementary mode of description. Indeed the use of words like thoughts and feelings does not refer to a firmly connected causal chain, but to experiences which exclude each other because they are conditioned by different separations between the conscious content and the background which we loosely term ourselves.

Especially instructive is the relation between experience of the feeling of volition and conscious pondering on motives for action. The indispensability of such apparently contrasting means of expression in the description of the richness of conscious life strikingly reminds us of the way in which elementary physical concepts are used in atomic physics. In such a comparison, however, 1958.

we must recognize not only that psychical experiences cannot be subjected to physical measurements, but that, moreover, the very concept of volition, far from referring to a generalization of deterministic description, from the outset aims at the possibilities of life. Without entering into the old philosophical discussion of the freedom of the will, I shall only remind you that in the objective description of our situation the use of the word will corresponds closely to that of words like hope and responsibility equally indispensable in human communication.

We have here reached problems which touch human fellowship and where the multifariousness of the means of expression is conditioned by the impossibility of characterizing, by any fixed separation, the role of the individual in the society. In view of the contrasts regarding established traditions, as well as their forms of expression, exhibited by human cultures developed under different conditions of life, one can, in a certain sense, call such cultures complementary. However, we are here in no way dealing with such definite mutually exclusive features as those we meet in the objective description of general problems of physics and psychology, but with differences in attitude, which can be appreciated or ameliorated by extended intercourse between peoples. In our time, when the increase of our knowledge and possibilities more than ever links the fate of all people, international collaboration in science has far reaching tasks which may be furthered not least by the reminiscence of general conditions of human knowledge.

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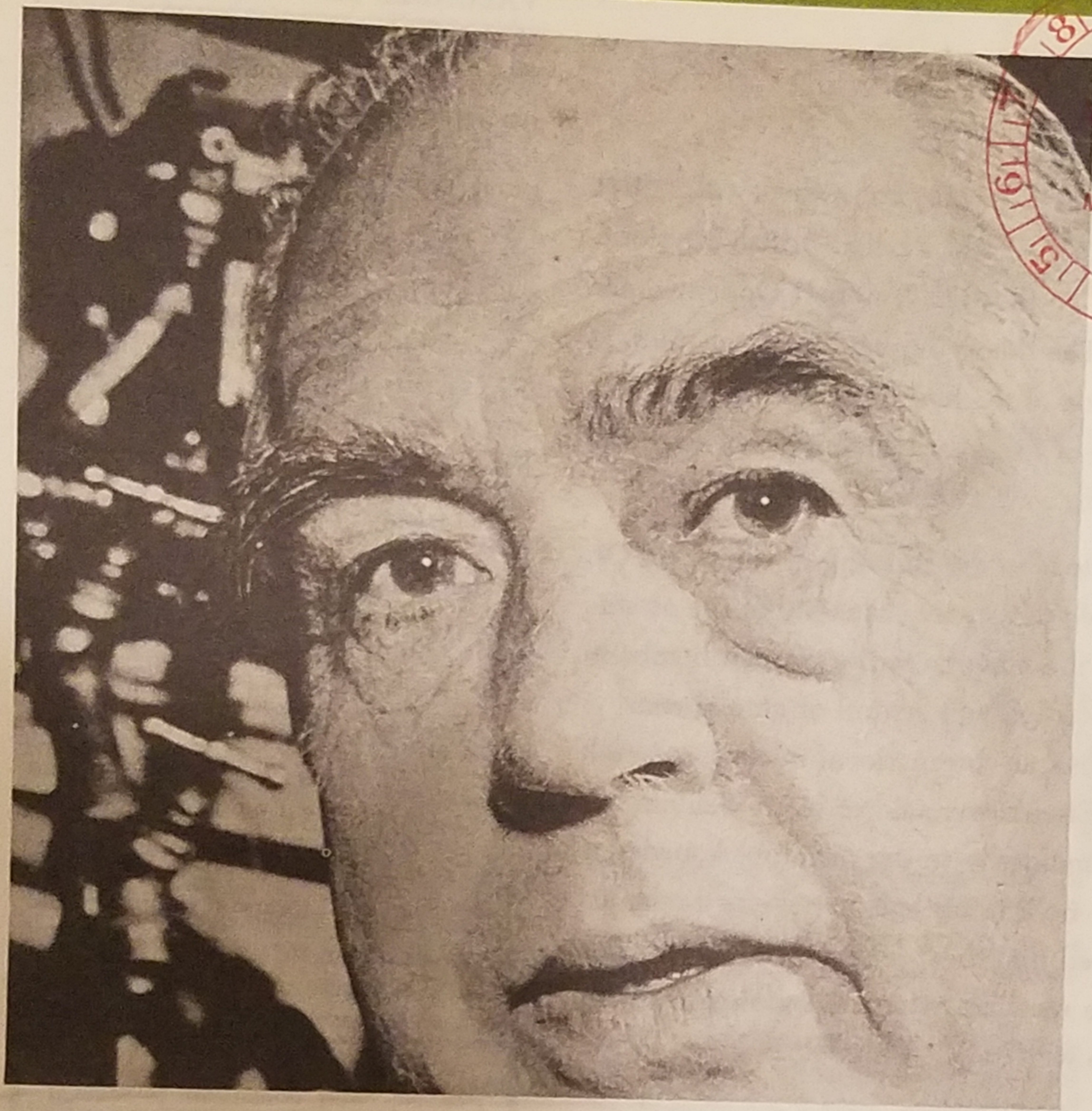
THE WORLD OF WILEY

NEW YORK · SPRING 1964



The Unity of Human Knowledge Niels Bohr

The question alluded to in the title for this address is as old as civilization itself, but has acquired renewed attention in our days with the increasing specialization of studies and social activities. From various sides concern has been expressed with the widespread confusion arising from the apparently divergent approaches taken by humanists and scientists to human problems, and in this connection there has even been talk about a cultural rift in modern society. We must, however, not forget that we are living in times of rapid developments in many fields of knowledge, reminiscent in such respect of the age of European Renaissance.

However great the difficulties of liberation from the medieval world view were felt at that time, the fruits of the so-called Scientific Revolution are certainly now a part of the common cultural background. In our century the immense progress of the sciences has not only greatly advanced technology and medicine but has at the same time given us an unsuspected lesson about our position as observers of that nature of which we are part ourselves. Far from implying a schism between humanism and physical science, this development entails a message of importance for our attitude to common human problems, which — as I shall try to show — has given the old question of the unity of knowledge new perspective.

The pursuit of scientific inquiry with the aim of augmenting and ordering our experience of the world around us has through the ages proved fertile, not least for the continual progress of technology which to so great an extent has changed the frame of our daily life. While early developments of astronomy, geodesy, and metallurgy in Egypt, Mesopotamia, India, and China were primarily directed to serve requirements of the community, it is in ancient Greece that we first meet with systematic endeavours to clarify the basic principles for the description and ordering of knowledge.

In particular, we admire the Greek mathematicians, who in many respects laid the firm foundation on which later generations have built. For our theme it is important to realize that the definition of

Comment

Half a century ago, Dr. Niels Bohr opened the way for a theory of matter that explained, in the words of Dr. P. A. M. Dirac, a noted British physicist, "most of physics and all of chemistry." To this, Dr. J. Robert Oppenheimer has added, "and therefore all of life." The theory is quantum mechanics. It began in 1913 with Dr. Bohr's explanation of the hydrogen atom. It remains, along with the theory of relativity, one of the great benchmarks of scientific thought in the first half of the twentieth century.

Although his research opened the door to the splitting of the atom, Dr. Bohr was always sensitive to the terrible destructive capacity of the atomic bomb. He urged that nations leave off the manufacturing of such bombs in time of peace and adopt a system of international control of atomic energy. He was a leader in the effort to establish an international nuclear research center in Geneva. Former President Eisenhower said of him: "Seldom has a man dedicated himself more single-mindedly to the search of knowledge for the benefit of mankind than has Dr. Bohr in his half century as a scientist and teacher." Albert Einstein described him thus: "Personally, Bohr is one of the most amiable colleagues I have met. He utters his opinions like one perpetually groping and never like one who believes himself to be in possession of definite truth."

We at Wiley were honored last year when the late Dr. Bohr's son, himself a distinguished scientist, wrote us asking whether we were interested in publishing a posthumous collection of his father's essays. We had served as publisher to Dr. Bohr on an earlier occasion; we were pleased to do so again. This issue of the WORLD OF WILEY carries an essay from Niels Bohr's latest book. I am hopeful you will find it valuable reading.

W Bradford Wiley

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Wiley Board Chairman Edward P. Hamilton has been elected a Trustee Member of the Engineering Index, Inc. This nonprofit organization is responsible for a number of important services to the engineering and scientific communities, including *Engineering Index*, an annual index and abstracting service, and the new monthly *Engineering Index*, initiated to help readers keep abreast of rapidly developing technology in all fields of engineering.

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All publications indexed are permanently filed in the Engineering Societies Library. Photoprints, microfilm, and translations of any article indexed may be obtained from the Library at minimal cost.

Paul Rosbaud, consultant to several scientific publishing houses and the first recipient of the Tate Medal of the American Institute of Physics, died in London on January 28, 1963, at the age of 66.

Dr. Rosbaud spent a long and fruitful career as a scientific editor. He had an unusual ability to stimulate the authors which, together with his charming and unassuming personality, made him instrumental in the creation of many great books, handbooks, and journals.

In 1956 Dr. Rosbaud became European editor for Interscience Publishers.

Charles G. Ramsey, architect and author, died on December 11, 1963, at the age of 79. Mr. Ramsey, a native of Dublin, came to this country in the early nineteen-hundreds. He was self-taught as an architect and was associated with several architectural firms in New York.

He was co-author of *Architectural Graphic Standards*, published by Wiley in 1933, and now in its fifth edition.

THE WORLD OF WILEY

published by
JOHN WILEY & SONS, INC.
Publishers of Books
New York Sydney London
as a service
to the Scientific Community

Address all
correspondence to the
editor, Frank Redding,
John Wiley & Sons, Inc.,
605 Third Avenue,
New York, N. Y. 10016.

The Unity of Human Knowledge

(Cover story continued)

mathematical symbols and operations is based on simple logical use of common language. Mathematics is therefore not to be regarded as a special branch of knowledge based on the accumulation of experience, but rather as a refinement of general language, supplementing it with appropriate tools to represent relations for which ordinary verbal expression is imprecise or too cumbersome.

In view of the apparent remoteness of mathematical abstractions, often frightening wider circles, it may be noted that even elementary mathematical training allows school disciples to see through the famous paradox of the race between Achilles and the tortoise. How could the fleet-footed hero ever catch up with and pass the slow reptile if it were given even the smallest handicap? Indeed, at his arrival at the starting point of the turtle Achilles would find that it had moved to some further point along the race track, and this situation would be repeated in an infinite sequence. I need hardly remind you that the logical analysis of situations of this type was to play an important role for the development of mathematical concepts and methods.

From the beginning, the use of mathematics has been essential for the progress of the physical sciences. While Euclidean geometry sufficed for Archimedes' elucidation of fundamental problems of static equilibrium, the detailed description of the motion of material bodies demanded the development of the infinitesimal calculus on which the imposing edifice of Newtonian mechanics rests. Above all, the explanation of the orbital motion of the planets in our solar system, based on simple mechanical principles and the law of universal gravitation, deeply influenced the general philosophical attitude in the following centuries and strengthened the view that space and time as well as cause and effect had to be taken as *a priori* categories for the comprehension of all knowledge.

The extension of physical experience in our days has, however, necessitated a radical revision of the foundation for the unambiguous use of our most elementary concepts, and has changed our attitude to the aim of physical science. Indeed, from our present stand-point physics is to be regarded not so much as the study of something *a priori* given, but rather as the development of methods for ordering and surveying human experience. In this respect our task must be to account for such experience in a manner independent of individual subjective judgment and therefore objective in the sense that it can be unambiguously communicated in the common human language.

As regards the very concepts of space and time reflected in the primitive use of words as here and there, and before and after, it is to be remembered how essential the immense speed of light propagation, compared with the velocities of the bodies in our neighbourhood, is for our ordinary orientation. However, the surprise that it proved impossible even by the most refined measurements to ascertain, in laboratory experiments, any effect of the orbital motion of the earth around the sun, revealed that the shape of rigid bodies and their mutual distances would be differently perceived by observers swiftly moving relative to each other, and that even events, which by one observer would be judged as simultaneous, by another could be reckoned as occurring at different moments. Far from giving rise to confusing complications, the recognition of the extent to which the account of physical experience depends on the standpoint of the observer proved most fertile in tracing fundamental laws valid for all observers.

Indeed, the general theory of relativity, by which Einstein in renouncing all ideas of absolute space and time gave our world picture a unity and harmony surpassing any previous dreams, offered an instructive lesson as regards the consistency and scope of plain language. Although the convenient formulation of the theory involves mathematical abstractions as four-dimensional non-Euclidean geometry, its physical interpretation rests fundamentally on every observer's possibility of maintaining a sharp separation between space and time and of surveying how any other observer, in his frame, will describe and coordinate experience by means of the common language.

New fundamental aspects of the observational problem, entailing a revision of the very foundation for the analysis of phenomena in terms of cause and effect, were to be uncovered by the development initiated by Planck's discovery of the universal quantum of action in the first year of this century. In fact, this discovery proved that the wide applicability of so-called classical physics rests entirely on the circumstance that the action involved in any phenomena on the ordinary scale is so large that the quantum can be completely neglected. In atomic processes, however, we meet with regularities of a novel kind, defying causal pictorial description but nevertheless responsible for the peculiar stability of atomic systems on which all properties of matter ultimately depend.

In this new field of experience, opened by modern refinements of the art of physical experimentation, we have met with many great surprises and even been faced with the problem of what kind of answers we can receive by putting questions to nature in the form of experiments. Indeed, in the account of ordinary experience it is taken for granted that the objects under investigation are not interfered with by the observation. It is true that when we

(continued on page 12)

The Unity of Human Knowledge

(Continued)

look at the moon in a telescope we receive light from the sun reflected from the moon-surface, but the recoil from this reflection is far too small to have any effect on the position and velocity of a body as heavy as the moon. If, however, we have to do with atomic systems, whose constitution and reactions to external influence are fundamentally determined by the quantum of action, we are in a quite different position.

Faced with the question of how under such circumstances we can achieve an objective description, it is decisive to realize that however far the phenomena transcend the range of ordinary experience, the description of the experimental arrangement and the recording of observations must be based on common language. In actual experimentation this demand is amply satisfied with the specification of the experimental conditions through the use of heavy bodies like diaphragms and photographic plates, the manipulation of which is accounted for in terms of classical physics. Just this circumstance, however, excludes any separate account of the interaction between the measuring instruments and the atomic objects under investigation.

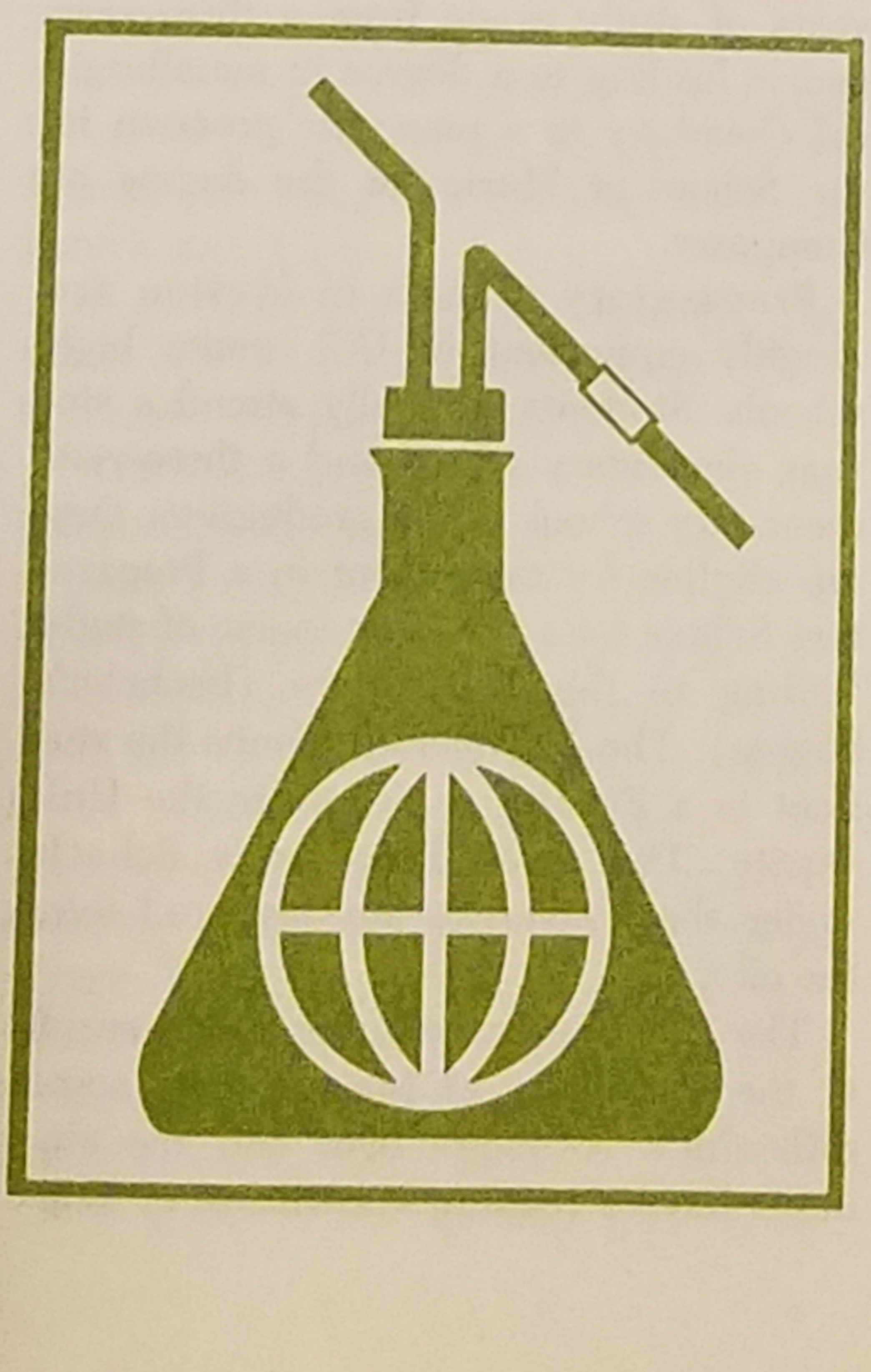
Especially this situation prevents the unlimited combination of space-time coordination and the conservation laws of momentum and energy on which the causal pictorial description of classical physics rests. Thus, an experimental arrangement aiming at ascertaining where an atomic particle, whose position at a given time has been controlled, will be located at a later moment implies a transfer, uncontrollable in principle, of momentum and energy to the fixed scales and regulated clocks necessary for the definition of the reference frame. Conversely, the use of any arrangement suited to study momentum and energy balance – decisive for the account of essential properties of atomic systems–implies a renunciation of detailed space-time coordination of their constituent particles.

Under these circumstances it is not surprising that with one and the same experimental arrangement we may obtain different recordings corresponding to various individual quantum processes for the occurrence of which only statistical account can be given. Likewise we must be prepared that evidence, obtained by different, mutual exclusive experimental arrangements, may exhibit unprecedented contrast and even at first sight appear contradictory.

It is in this situation that the notion of complementarity is called for to provide a frame wide enough to embrace the account of fundamental regularities of nature which cannot be comprehended within a single picture. Indeed, evidence obtained under well-defined experimental conditions – and expressed by adequate use of elementary physical concepts – exhausts in its entirety all information about the atomic objects which can be communicated in common language.

A detailed account on complementary lines of a new wide domain of experience has been possible by the gradual establishment of a mathematical formalism, known as quantum mechanics, in which the elementary physical quantities are replaced by symbolic operators subject to an algorism, involving the quantum of action and reflecting the non-commutativity of the corresponding measuring operations. Just by treating the quantum of action as an element evading customary explanation – similar to the role of the velocity of light in relativity theory as a maximal speed of signals – this formalism can be regarded as a rational generalization of the conceptual framework of classical physics. For our theme, however, the decisive point is that the physical content of quantum mechanics is exhausted by its power to formulate statistical laws governing observations obtained under conditions specified in plain language.

The fact that in atomic physics, where we are concerned with regularities of unsurpassed exactness, objective description can be achieved only by including in the account of the phenomena explicit reference to the experimental conditions, emphasizes in a novel manner the inseparability of knowledge and our possibilities of inquiry. We are here concerned with a general epistemological lesson illuminating our position in many other fields of human interest.



In particular, the conditions of analysis and synthesis of so-called psychic experiences have always been an important problem in philosophy. It is evident that words like thoughts and sentiments, referring to mutually exclusive experiences, have been used in a typical complementary manner since the very origin of language. In this context, however, the subject-object separation demands special attention. Every unambiguous communication about the state and activity of our mind implies, of course, a separation between the content of our consciousness and the background loosely referred to as "ourselves", but any attempt at exhaustive description of the richness of conscious life demands in various situations a different placing of the section between subject and object.

In order to illustrate this important point, I shall allow myself to quote a Danish poet and philosopher, Poul Martin Moller, who lived about a hundred years ago and left behind an unfinished novel still read with delight by the older as well as the younger generation in this country. In his novel, called *The Adventures of a Danish Student*, the author gives a remarkably vivid and suggestive account of the interplay between the various aspects of our position, illuminated by discussions within a circle of students with different characters and divergent attitudes to life.

Especially I shall refer to a conversation between two cousins, one of whom is very soberly efficient in practical affairs, of the type which then, and even now, is known among students as a philistine, whereas the other, called the licentiate, is addicted to remote philosophical meditations detrimental to his social activities. When the philistine reproaches the licentiate for not having made up his mind to use the opportunities for finding a practical job, offered him by the kindness of his friends, the poor licentiate apologizes most sincerely, but explains the difficulties in which his reflections have brought him.

Thus he says:

> My endless enquiries make it impossible for me to achieve anything. Furthermore, I get to think about by own thoughts of the situation in which I find myself. I even think that I think of it, and divide myself into an infinite retrogressive sequence of "I"s who consider each other. I do not know at which "I" to stop as the actual, and in the moment I stop at one, there is indeed again an "I" which stops at it. I become confused and feel a dizziness as if I were looking down into a bottomless abyss, and my ponderings result finally in a terrible headache.

In his reply the cousin says:

> I cannot in any way help you in sorting your many "I"s. It is quite outside my sphere of

> action, and I should either be or become mad as you if I let myself in for your superhuman reveries. My line is to stick to palpable things and walk along the broad highway of common sense; therefore my "I"s never get tangled up.

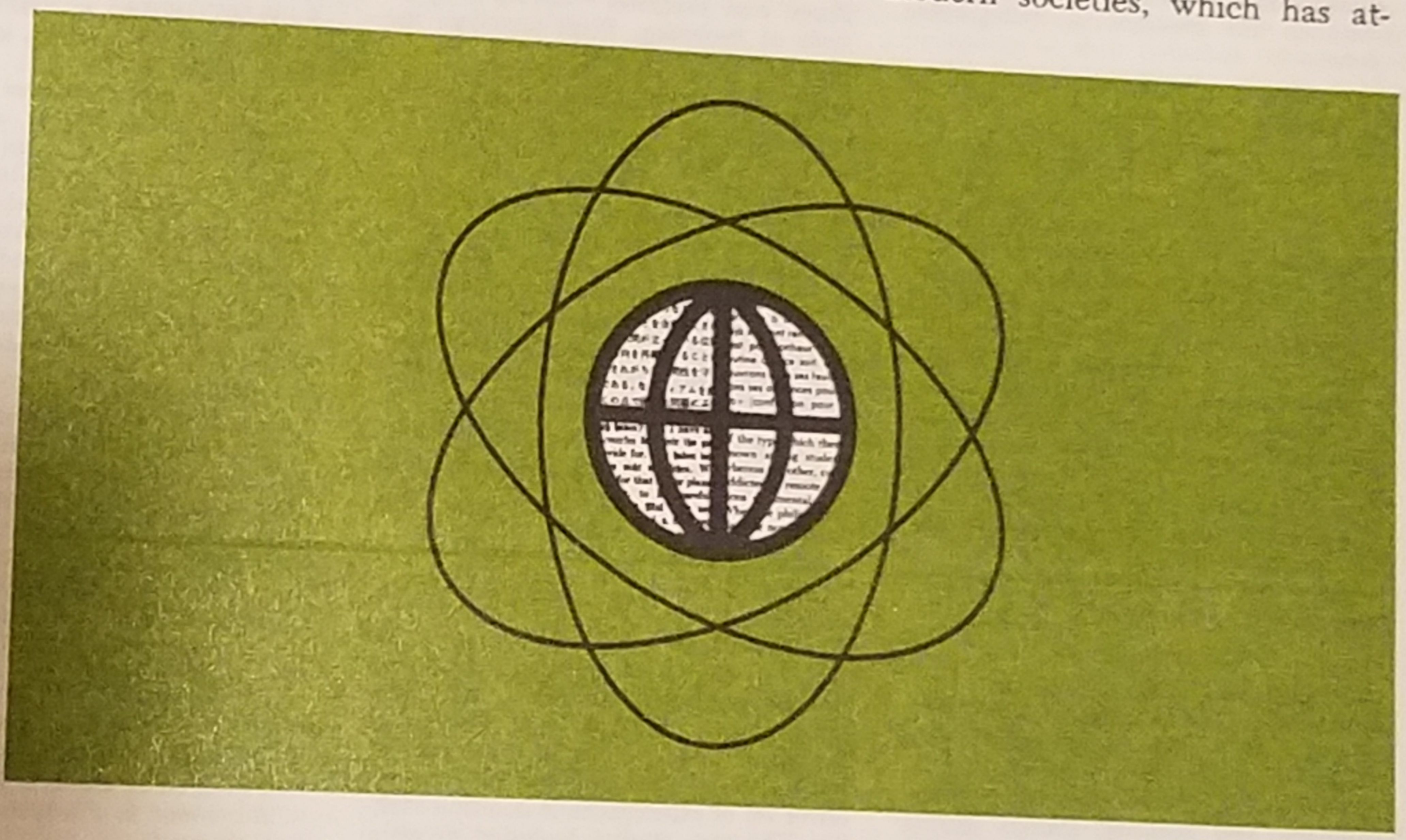
Quite apart from the fine humour with which the story is told, it is certainly not easy to give a more pertinent account of essential aspects of the situation with which we all are faced. Fortunately, the risk of falling into the deplorable situation of the licentiate is small in normal life, where we become gradually accustomed to coping with practical necessities and learn to communicate in common language what we need and what is on our mind. In such adjustment the balance between seriousness and humour, conspicuous in children's play and equally appreciated in mature life, plays no small part.

The complementary way in which words like contemplation and volition are used has especially to be taken into account when turning to the problem of the freedom of will, discussed by philosophers through the ages. Even if we cannot say whether we want to do something because we gather that we can, or we can only do it because we will, the feeling of, so to speak, being able to make the best out of circumstances is a common human experience. Indeed, the notion of volition plays an indispensable part in human communication similar to words like hope and responsibility, in themselves equally undefinable outside the context in which they are used.

The flexibility of the subject-object separation in the account of conscious life corresponds to a richness of experience so multifarious that it involves a variety of approaches. As regards our knowledge of fellow beings, we witness, of course, only their behaviour, but we must realize that the word consciousness is unavoidable when such behaviour is so complex that its account in common language entails reference to self-awareness. It is evident, however, that all search for an ultimate subject is at variance with the aim of objective description, which demands the contraposition of subject and object.

Such considerations involve no lack of appreciation of the inspiration which the great creations of art offer us by pointing to features of harmonious wholeness in our position. Indeed, in renouncing logical analysis to an increasing degree and in turn allowing the play on all strings of emotion, poetry, painting, and music contain possibilities of bridging between extreme modes as those characterized as pragmatic and mystic. Conversely, already ancient Indian thinkers understood the logical difficulties in giving exhaustive expression for such wholeness. In particular, they found escape from apparent disharmonies in life by stressing the futility of demanding an answer to the question of the meaning of existence, realizing that any use of the word "meaning" implies comparison; and with what can we compare the whole existence?

The aim of our argumentation is to emphasize that all experience, whether in science, philosophy, or art, which may be helpful to mankind, must be capable of being communicated by human means of expression, and it is on this basis that we shall approach the question of unity of knowledge. Confronted with the great diversity of cultural developments, we may therefore search for those features in all civilizations which have their roots in the common human situation. Especially we recognize that the position of the individual within the community exhibits in itself multifarious, often mutually exclusive, aspects.

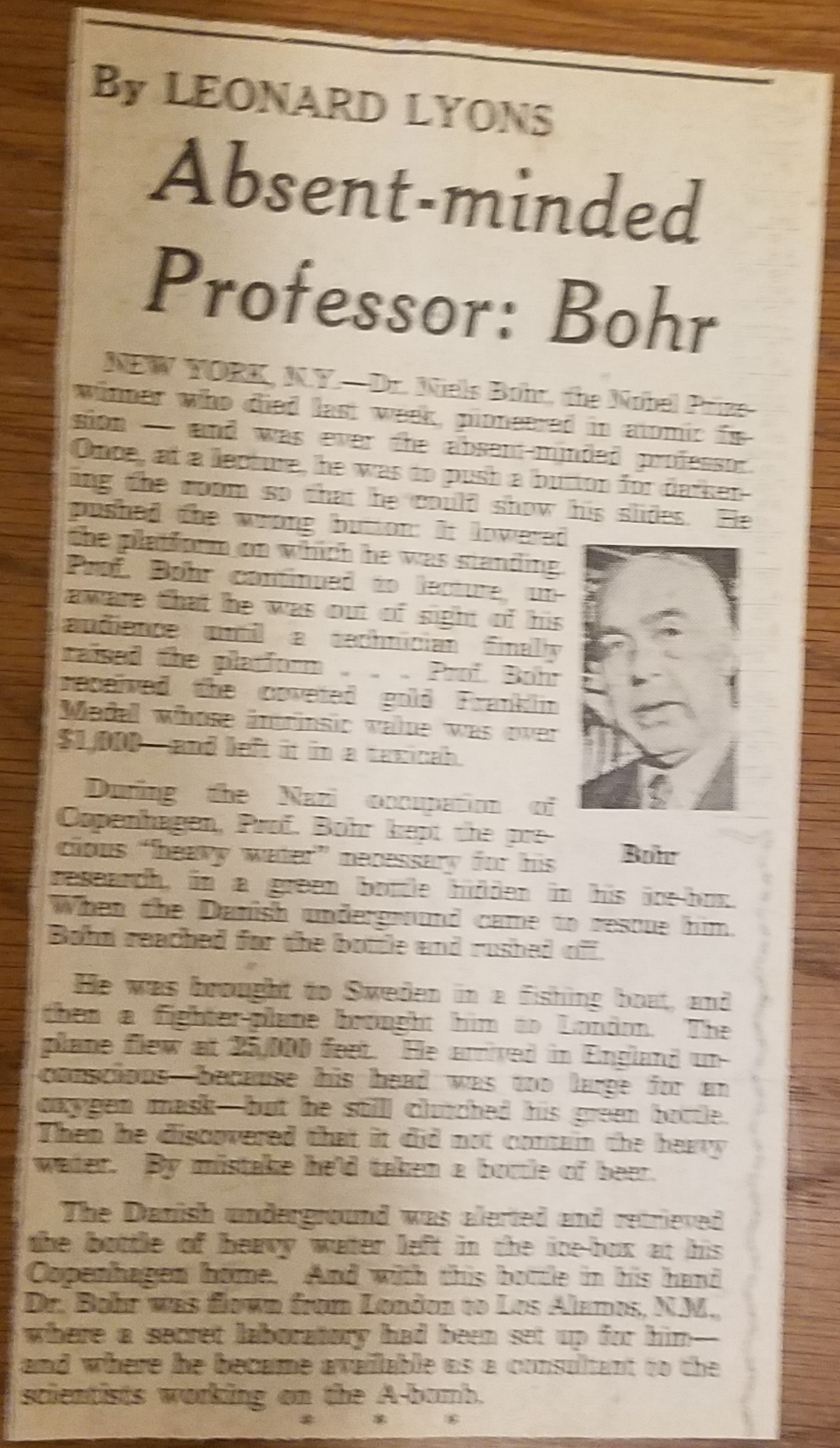


When approaching the age-old problem of the foundation of so-called ethical values we shall in the first place ask about the scope of such concepts as justice and charity, the closest possible combination of which is attempted in all human societies. Still it is evident that a situation permitting unambiguous use of accepted judicial rules leaves no room for the free display of charity. But, as stressed especially by the famous Greek tragedians, it is equally clear that compassion can bring everyone in conflict with any concisely formulated idea of justice. We are here confronted with complementary relationships inherent in the human position, and unforgettably expressed in old Chinese philosophy, reminding us that in the great drama of existence we are ourselves both actors and spectators.

In comparing different national cultures we meet with the special difficulty of appreciating the culture of one nation in terms of traditions of another. In fact, the element of complacency inherent in every culture corresponds closely to the instinct of self-preservation characteristic for any species among the living organisms. In such context it is, however, important to realize that the mutually exclusive characteristics of cultures, resting on traditions fostered by historical events, cannot be immediately compared to those met with in physics, psychology, and ethics, where we are dealing with intrinsic features of the common human situation.

In fact, as is not least conspicuous in European history, contact between nations has often resulted in the fusion of cultures retaining valuable elements of the original national traditions. The question of how to ameliorate the so-called cultural rift in modern societies, which has attracted so much attention at this meeting, is after all a more restricted educational problem, the attitude to which would seem to call not only for information but, as I think everyone will agree, also for some humour. A most serious task is, however, to promote mutual understanding between nations with very different cultural background.

Indeed, the rapid progress of science and technology in our days, which entails unique promises for the promotion of human welfare and at the same time imminent menaces to universal security, presents our whole civilization with a veritable challenge. Certainly, every increase in knowledge and potentialities has always implied a greater responsibility, but at the present moment, when the fate of all peoples is inseparably connected, a collaboration in mutual confidence, based on appreciation of every aspect of the common human position, is more necessary than ever before in the history of mankind.



By LEONARD LYONS

Absent-minded Professor: Bohr

NEW YORK, N.Y.—Dr. Niels Bohr, the Nobel Prize-winner who died last week, pioneered in atomic fission — and was ever the absent-minded professor. Once, at a lecture, he was to push a button for darkening the room so that he could show his slides. He pushed the wrong button: It lowered the platform on which he was standing. Prof. Bohr continued to lecture, unaware that he was out of sight of his audience until a technician finally raised the platform . . . Prof. Bohr received the coveted gold Franklin Medal whose intrinsic value was over $1,000—and left it in a taxicab.

Bohr

During the Nazi occupation of Copenhagen, Prof. Bohr kept the precious "heavy water" necessary for his research, in a green bottle hidden in his ice-box. When the Danish underground came to rescue him, Bohr reached for the bottle and rushed off.

He was brought to Sweden in a fishing boat, and then a fighter-plane brought him to London. The plane flew at 25,000 feet. He arrived in England unconscious—because his head was too large for an oxygen mask—but he still clutched his green bottle. Then he discovered that it did not contain the heavy water. By mistake he'd taken a bottle of beer.

The Danish underground was alerted and retrieved the bottle of heavy water left in the ice-box at his Copenhagen home. And with this bottle in his hand Dr. Bohr was flown from London to Los Alamos, N.M., where a secret laboratory had been set up for him—and where he became available as a consultant to the scientists working on the A-bomb.

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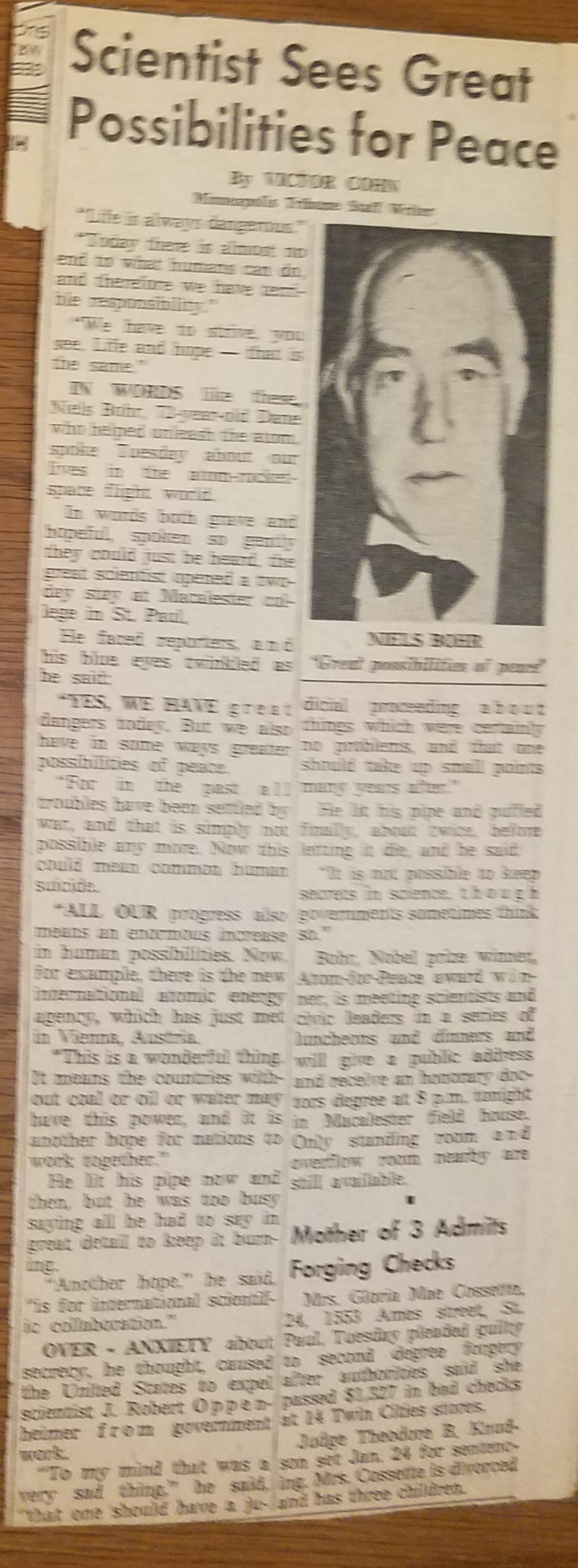

Scientist Sees Great Possibilities for Peace

By VICTOR COHN
Minneapolis Tribune Staff Writer

"Life is always dangerous."

"Today there is almost no end to what humans can do, and therefore we have terrible responsibility."

"We have to strive, you see. Life and hope — that is the same."

IN WORDS like these, Niels Bohr, 72-year-old Dane who helped unleash the atom, spoke Tuesday about our lives in the atom-rocket-space flight world.

In words both grave and hopeful, spoken so gently they could just be heard, the great scientist opened a two-day stay at Macalester college in St. Paul.

He faced reporters, and his blue eyes twinkled as he said:

NIELS BOHR
'Great possibilities of peace'

"YES, WE HAVE great dangers today. But we also have in some ways greater possibilities of peace.

"For in the past all troubles have been settled by war, and that is simply not possible any more. Now this could mean common human suicide.

"ALL OUR progress also means an enormous increase in human possibilities. Now, for example, there is the new international atomic energy agency, which has just met in Vienna, Austria.

"This is a wonderful thing. It means the countries without coal or oil or water may have this power, and it is another hope for nations to work together."

He lit his pipe now and then, but he was too busy saying all he had to say in great detail to keep it burning.

"Another hope," he said, "is for international scientific collaboration."

OVER - ANXIETY about secrecy, he thought, caused the United States to expel scientist J. Robert Oppenheimer from government work.

"To my mind that was a very sad thing," he said, "that one should have a judicial proceeding about things which were certainly no problems, and that one should take up small points many years after."

He lit his pipe and puffed finally, about twice, before letting it die, and he said:

"It is not possible to keep secrets in science, though governments sometimes think so."

Bohr, Nobel prize winner, Atom-for-Peace award winner, is meeting scientists and civic leaders in a series of luncheons and dinners and will give a public address and receive an honorary doctors degree at 8 p.m. tonight in Macalester field house. Only standing room and overflow room nearby are still available.

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Mother of 3 Admits Forging Checks

Mrs. Gloria Mae Cossette, 24, 1553 Ames street, St. Paul, Tuesday pleaded guilty to second degree forgery after authorities said she passed $1,327 in bad checks at 14 Twin Cities stores.

Judge Theodore B. Knudson set Jan. 24 for sentencing. Mrs. Cossette is divorced and has three children.

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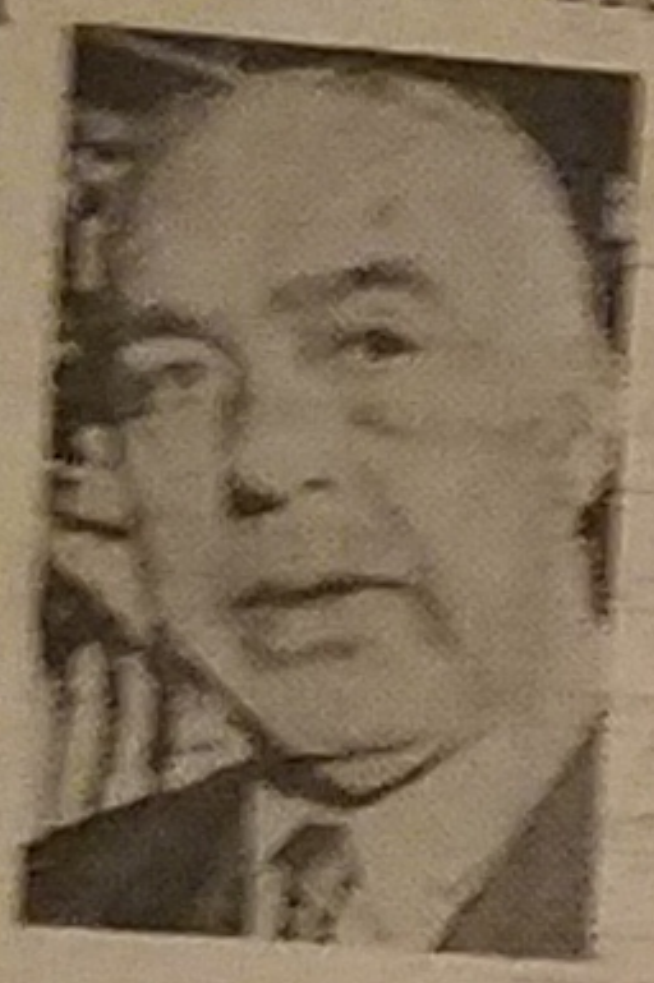

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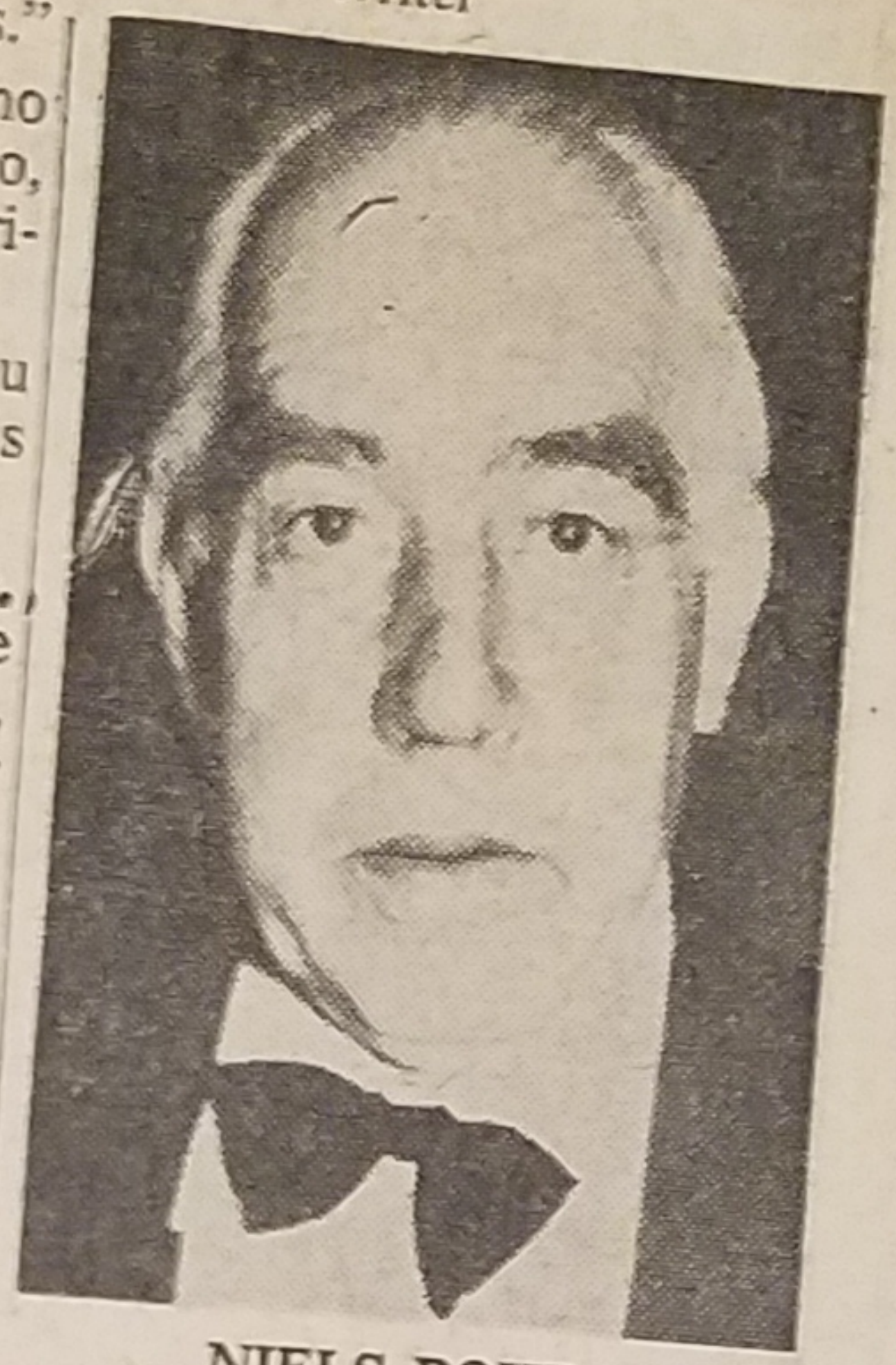

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Bohr Says F
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By VICTO
Minneapolis Tribu

"We of the free countries" have the greatest resources "to improve the critical human situation."

This was the challenge for free peoples that Dr. Niels Bohr, Danish scientist, stated Wednesday night before 4,500 persons at Macalester college in St. Paul.

He led to it by taking the 4,500 down a rich, one-hour path touching some of the progress in modern science that has brought him honor after honor.

THE LAEST of these, an honorary doctor of science degree, was conferred on him by Macalester president Charles J. Turck last night.

For a long, quiet hour the 72-year-old physicist described something of physics and thought—and his belief that "the knowledge we have gained in exploration of the atom has application in wide fields of human interest."

He recognized that there is a "new situation in the history of mankind" because of the recent work of science and technology—a danger of wiping out man.

Then he concluded:

"MY POINT is this. In science, new problems demand new approaches.

"Now, we must think, all of us, of the new approaches to human relationship, especially international relations, demanded by this completely new situation.

"And in the countries where by happy development and traditions there is a great liberty for individuals, and open discussion, we are in a better state than in countries where there is not that freedom."

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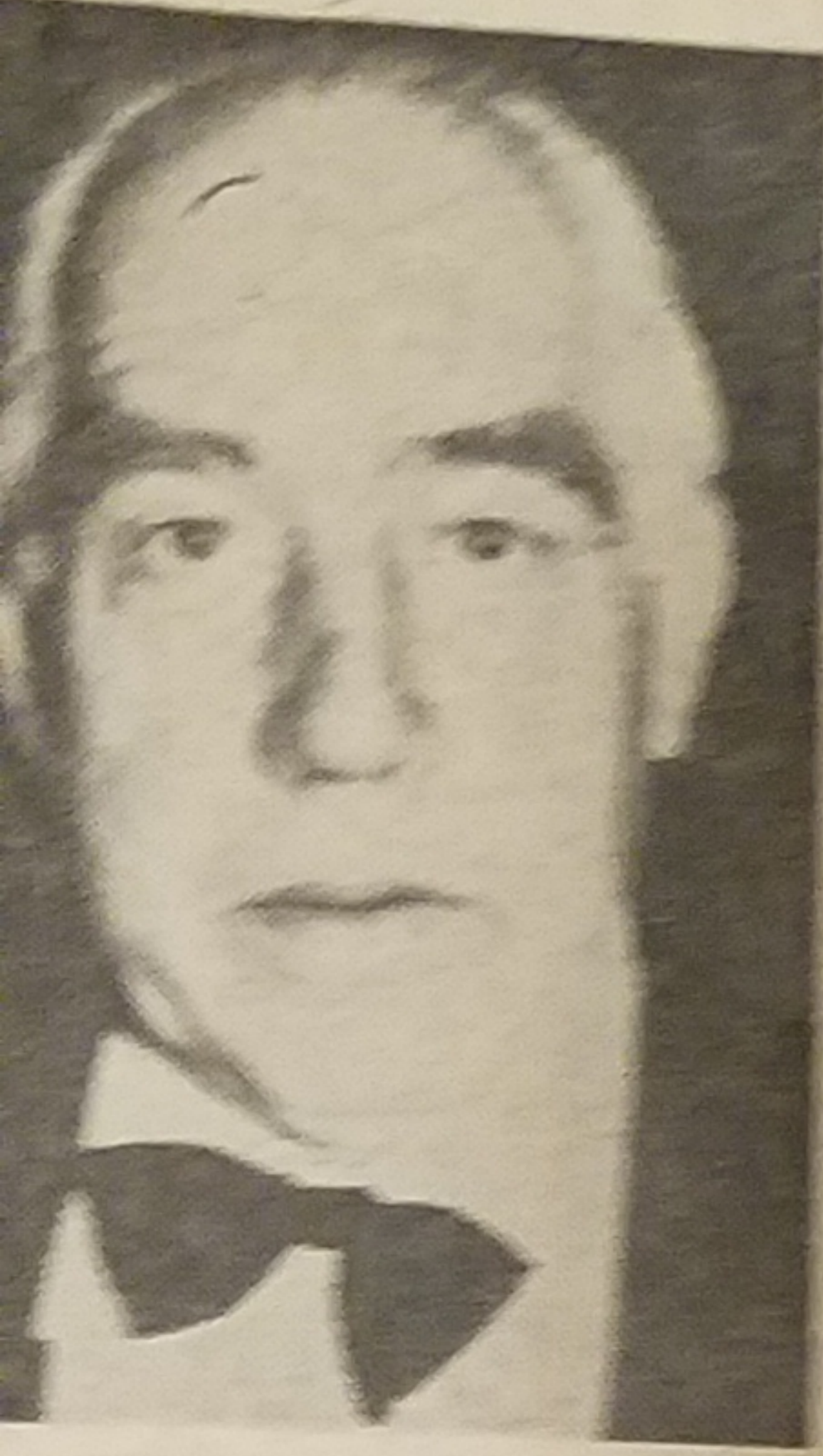

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He lit his worn pipe often as he listened to questions, then cupped it in his always flexing hands and studied it from under shaggy eyebrows as he replied.

His rumbling voice remained soft, even when he glanced intently at newsmen to see that they grasped the urgency he felt for mankind today. His voice was so quiet it was occasionally lost in the scratching of pens and pencils on notepads.

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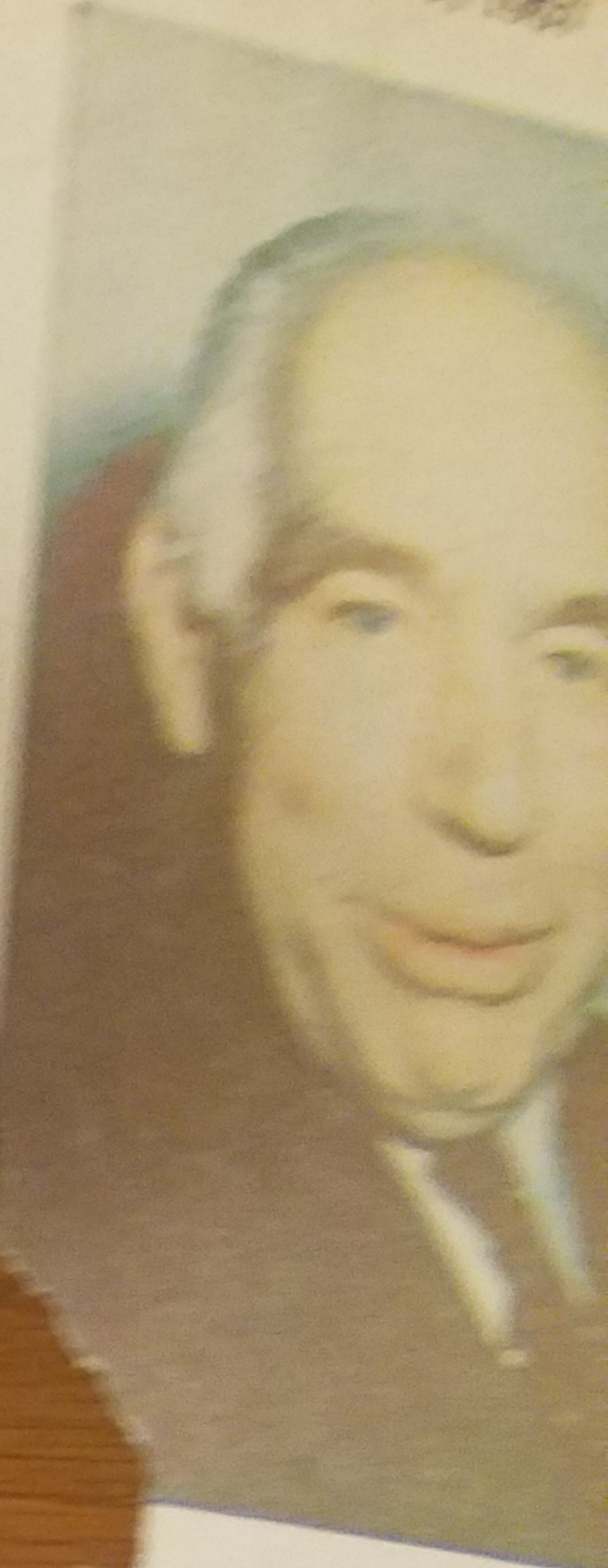

NIELS HENRIK BOHR

Feels 'hopeful' for mankind

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By HAL

Minneapolis Star Staff Writer

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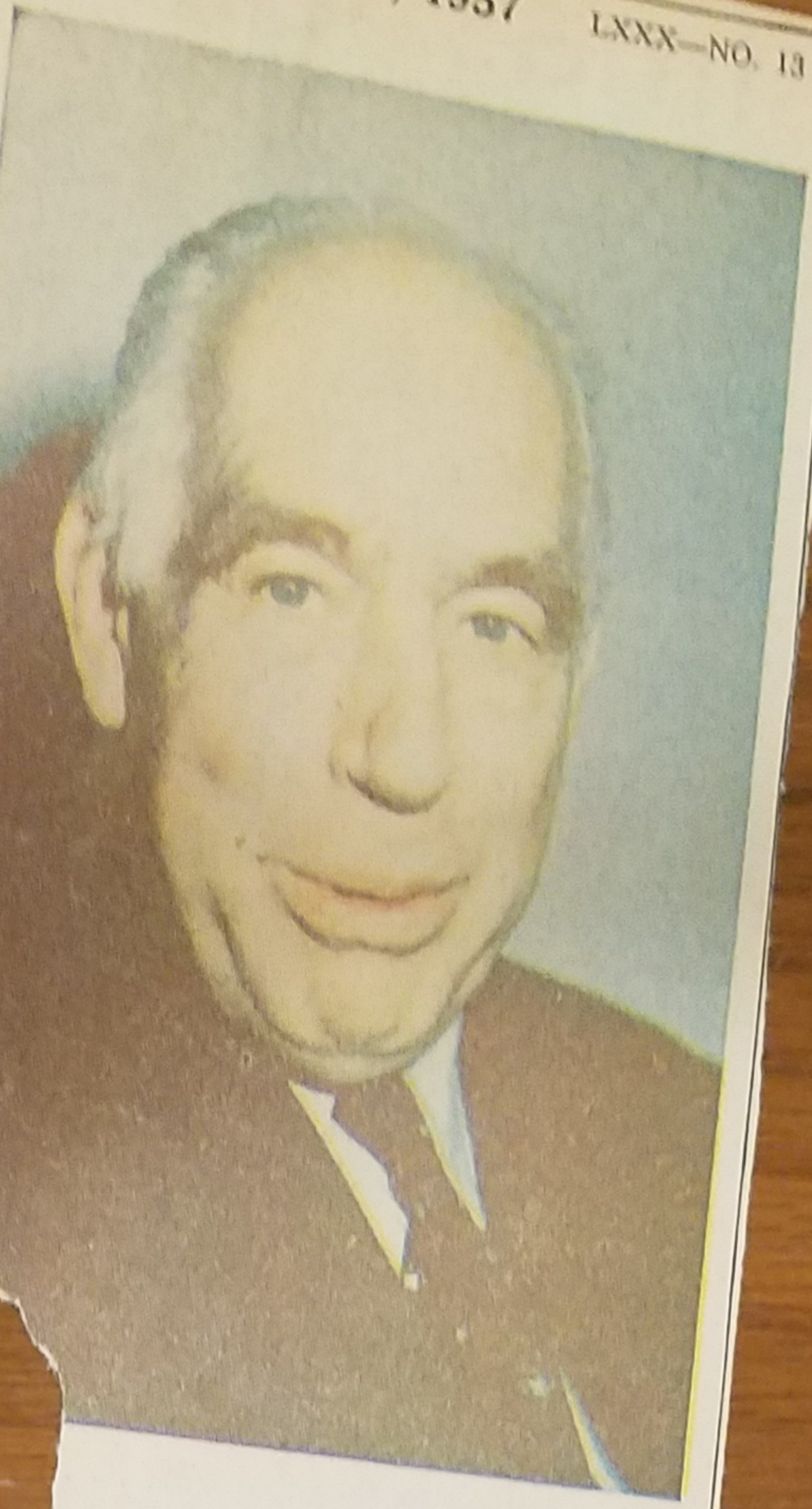
Tuesday, Dec. 10, 1957 LXXX—NO. 13



Associated Press photo.

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NATIVE SUICIDE'

entist Bohr Sees
ope' for Humanity

By HAL SEYMOUR
Minneapolis Star Staff Writer

of all nations must realize the unique opportunity
rent scientific achievement awards them and unite
ndly competition" for the benefit of all mankind,
physicist Niels Henrik Bohr said today in the Twin Cities.

Bohr, long an advocate of peaceful scientific development and winner of the first "atom for peace" award, told newsmen he could not help but be optimistic when the alternative presented in today's world situation was "common human suicide."

The world-famous scientist and atomic theorist will speak Wednesday night at Macalester college, dealing in part with his concept of "complementarity."

In explaining this concept today, Bohr noted the theory—developed in the field of atomic physics — applied equally to all aspects of human endeavor.

It holds that results obtained in research and study are related to the manner in which the investigation is made. In isolating part of what is under study, man may kill or lose that part because it exists complementary to the whole.

This, Bohr said, applies to the psychologies, sociologies, "to all fields including ethical values," as well as the physical sciences.

Because of this, Bohr said, the great technological advances of this age can provide "something quite unexpected" to the benefit of all mankind — a new "attitude" toward problems of

BOHR
Turn to Page 4A

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AFL-CIO

ATLANTIC CITY, N. J.—
AP)—AFL-CIO chiefs moved
oday to restore the 40,000-
member United Textile Work-
ers union (UTW) to good standing but ticketed the 132,000-member Bakery Workers union for ouster Thursday.

The appeals committee of the AFL-CIO convention accepted a signed statement from UTW leaders pledging full compliance with AFL-CIO directives to reform allegedly corrupt conditions in the union.

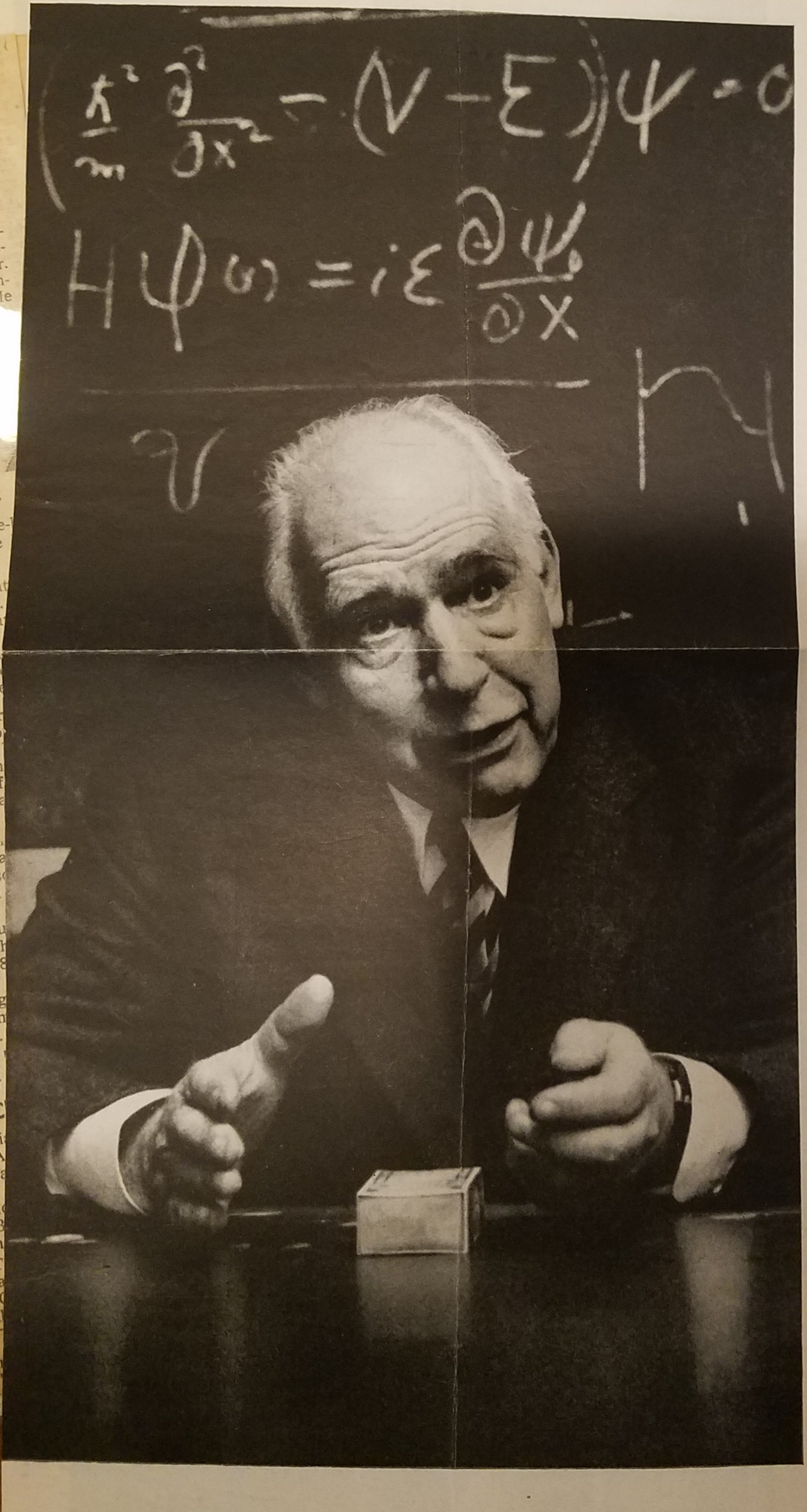
The appeals group then recommended that UTW suspension from the federation be cancelled and the union restored to good standing.

The UTW had faced expulsion action, such as already has been voted for the giant Teamsters union, also on corruption charges.

The AFL-CIO executive council this morning ordered the Bakery Workers union expelled by noon Thursday if James G. Cross, union president involved in corruption charges, continues refusal to surrender his office.

Cross

Erudite, Human Dr. Bohr



WHENEVER nuclear physicists come up with a new idea," said one of them recently, "their first thought is 'I'd better consult Professor Bohr about this.'" The enormous regard in which fellow scientists hold Niels Bohr was reaffirmed last month when the 71-year-old Danish physicist won the first $75,000 Atoms for Peace Award. In Copenhagen, where he still actively directs the Institute for Theoretical Physics he founded 37 years ago, Dr. Bohr was, characteristically, surprised by the news. He is a modest, temperate man and almost the only thing he seems incapable of comprehending is his awesome international renown.

Bohr, whom his friend Albert Einstein called "one of the greatest scientific discoverers of our age," published in 1913, at the age of 28, three treatises on atomic structure which in large measure laid the theoretical groundwork for the present atomic age. In 1922 he won the Nobel Prize. In 1939 at Princeton, he announced, in collaboration with J. A. Wheeler, the identity of Uranium-235 and prophesied "a chain action and atomic explosion of enormous proportion." In 1943, in one of the cloak-and-dagger dramas of the war, he was smuggled from Nazi-occupied Denmark to Sweden in the cabin of a fishing boat, flown to England in the bomb bay of an R.A.F. plane and thence to Los Alamos for work on the atomic bomb.

Long before the bomb's completion he foresaw its postwar significance and in 1944 broached the subject of international control in a letter to President Roosevelt. He believes now, as then, that "the very fact that knowledge is the basis for civilization points to openness [*i.e.*, international scientific cooperation] as the way to overcome the present crisis." This belief is the basis for his institute, the world capital of theoretical physics, which last year was given a $200,000 grant by the Ford Foundation.

Dr. Bohr lives in a big "mansion of honor," provided for life to each foremost Danish man of science. There he is happily surrounded by his wife Margrethe, his four sons and 12 grandchildren. He is a man of deep affection, warm humor but no small talk whatever. "I must make a little philosophy in everything," he explains.

SEATED before a figure-covered blackboard, Professor Niels Bohr talks to scientists visiting his Institute for Theoretical Physics.

"The exploration of nature has not only revolutionized the frame of our life but it is a deeply human endeavor which through the ages has united men in the attempt to clarify the common basis for knowledge. The pleasure and experience of these discussions is that one can forget oneself completely and think only of the subject matter and the gist of the questions raised by other participants."

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Niels Bohr